Carbohydrate, N, P and K status of developing rice (*Oryza sativa* L.) plants grown in the first and second crop seasons in Taiwan[1]

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Abstract : Concentrations of total nonstructural carbohydrates, N, P and K in different plant parts of rice were analyzed at stages of plant development. Differences between crop seasons were also studied to investigate the physiological causes of low yield of the second crop rice.

Accumulation of total nonstructural carbohydrates (TNC) in culms and leaf sheaths was most evident during the period of panicle development. Highest TNC concentration was recorded earlier in the second crop (25 days before heading) than in the first crop (18 days before heading) for rices grown in Taichung. It occurred at heading stage in both crops in Taipei area. The first crop rice accumulated significantly higher amount of TNC in culms at panicle emergence than the second crop rice.

Concentration of N was higher in leaf blades whereas those of P and K were higher in culms and leaf sheaths. Nitrogen concentration in plant tissues was higher in the first crop during the vegetative growth stage but the difference between crops was less significant as rices grew toward heading. Leaf blades of the second crop rice were considerably lower in K concentration than those of the first crop rice throughout the whole developmental period.

Less TNC stored in culms and leaf sheaths before heading, lower K concentration in leaf blades, and the composition, rather than concentration, of N were suggested as possible physiological causes affecting yield potential of the second crop rice in Taiwan.

Carbohydrates in the form of sugars, starch and other polysaccharides usually reach a maximum concentration in the leaf sheaths and culms of rice plants before the emergence of panicles. The stored carbohydrates could be either retranslocated to the panicles or consumed by respiration during the following grain-filling period. The importance of such carbohydrates in relation to grain yield of many cereal crops has long been a subject of interest as reported by many researchers [2,7,15,16,20,21,26] Although

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Lian and Tanaka [7] suggested that in rice, carbon assimilated before flowering was used for grain filling with relatively low efficiency, Yoshida and Ahn [26] assessed the contribution could be as high as 38% of total grain yield. By using ^{14}C, Cock and Yoshida [2] further acknowledged that with a translocation efficiency of 68 to 77 %, the contribution of stored carbohydrates to grain carbohydrates was 24 to 27%, which was equivalent to 1.9 to 2.1 t/ha of rough rice at 14% moisture.

Environmental conditions were usually considered important in influencing rice physiology and causing the low yield of the second crop rice in Taiwan. By statistical analysis of changes in dry weight, Wu *et al.* [24] estimated that preheading storage in the vegetative parts accounted for 14 and 21% of total grain yield for the first and second rice crops, respectively. However, differences in carbohydrate metabolism between the two crops has not been verified so far. A series of experiments were conducted in this laboratory to investigate the carbohydrate status and its impact on the development and yield performances of rice plants. We reported here the changes in concentrations of total nonstructural carbohydrates, nitrogen, potassium and phosphorus in different plant fractions from transplanting to heading. The results on redistribution of stored carbohydrates to panicles and the influences of environmental factors and cultural practices will be published elsewhere.

Materials and Methods

Japonica rice Tainung No. 61 and long-grain indica rice Chianung sen No. 11 were transplanted and grown in the experimental farm of Taiwan Agricultural Research Institute at Taipei, Taiwan in the second crop season of 1976 and the first crop season of 1977. After the Institute had moved to Taichung, japonica rices Tainan No. 5 and Tainung No. 67, and indica rices Taichung sen No. 5 and Taichung Native No. 1 were grown in the first and second crop seasons of 1978. All the experiments were set in 5× 9.5m plots with six replications in a randomized complete block design. Planting density was 22.5×22.5 cm. A soil test held in Taichung (1978) just before transplanting of the second crop rice indicated 1.09 % organic matter, 12.5 ppm available P, 24.0 ppm available K, and 10.6 meq/100g soil of CEC ; pH was 6.60. Before transplanting, N, P and K were applied to the paddy field at, respectively, 40, 60 and 45 kg/ha in the first and 35, 60 and 50 kg/ha in the second rice crop. Additional nitrogen at a rate of 30 kg/ha each was topdressed twice in both crops.

At intervals between transplanting and heading, the above-ground portion of 6 to 8 rice plants was harvested from each replication. After cleaning with tap and distilled water, one set of plants was then divided into leaf blade (referred to hereinafter as leaf) and culms plus leaf sheaths (culm). Samples were dried in an air-drafted oven at 100°C for 1 to 1.5 hrs followed by 70°C until dryness (4 to 5 hrs or longer if necessary). This method of drying was reported by Raguse and Smith [18] as capable of giving values of total nonstructural carbohydrates (TNC) approximately most closely to those from freeze-dried tissue. After dry weight had been determined, the samples were ground with a Wiley mill through a 40-mesh screen. Concentration of total nonstructural

carbohydrates were then determined according to Smith[19]. Ground samples were first hydrolyzed with takadiastase ("Clarase 900" or "Clarase 40,000", obtained from Miles Laboratories Inc., U. S. A.) at 40°C for 44 hrs, and reducing sugars were measured by the Shaeffer-Somogyi copperiodometric titration method described by Heinze and Murneek (cf. [19]).

Samples obtained from 1978 experiments were also analyzed for some major elements. Nitrogen was determined by semi-micro Kjeldahl procedures. For K and P analyses, a 0.5000 g of dried ground tissue was weighed into a 50-ml Vycor crucible. Duplicate weights of each sample were placed into a cool muffle furnace and muffled at 550°C for 5 to 6 hrs[5]. After ashing, the residue was taken up in 5 ml of HCl (1+3), transferred to 50-ml volumetric flask by filtering through Whatman No. 2 filter paper, and diluted to the mark with hot, double distilled water. Potassium was determined by using a Corning Model 400 flame photometer. Phosphorus was determined by the colorimetric-(Mo) blue method[1] and was read at 650 nm with a Perkin-Elmer Model 55 UV-VIS spectrophotometer.

Results

For the four rice varieties grown in 1978, leaf dry weight increased gradually but steadily up to 72 days after transplanting (DAT) in the first crop and to 60 DAT in the second crop (data not shown). It then decreased slightly toward heading. Maximum rate of increasing leaf dry weight occured between 50 to 72 DAT in the first crop and between 26 to 51 DAT in the second crop season. The second crop rice was more leafy and thus had higher leaf dry weight than the first crop rice at the time of panicle emergence. However, an accelerated leaf senescence was observed in the field during the grain-filling period of the second crop rice . As for the dry weight of culms, maximum rate of increase started 50 and 40 days after transplanting for the first and second crops, respectively, and continued until heading stage. Average culm dry weight of the four varieties was slightly higher for the first crop rice. No significant difference in total dry weight was found between crops. Comparison among varieties showed that Taichung sen No. 5 had the highest total dry weight followed by Tainung No. 67, Taichung Native No. 1 and Tainan No. 5 in that order in both crop seasons.

Concentrations of total nonstructural carbohydrates (TNC) were higher in culms than in leaf blades regardless of variety, location or crop season considered (Figs. 1 and 2). For experiment held in 1976-1977 at Taipei, it was noted that TNC concentration of rice seedlings was higher in the first than in the second crop, presumably due to lower temperature during the nursery period. Fig. 1 showed that TNC concentration in leaf blades of Tainung No. 61 rice grown in the first crop season decreased sharply in the early vegetative growth stage, reached a minimum between 40 to 70 days after transplanting, and increased gradually toward heading. It was higher for the first (8.6 %) than for the second (6.2%) crop rice at the time of panicle emergence. A similar trend was also recorded in leaf blades of Chianung sen No. 11 rice with the exceptions that in the first crop TNC concentration decreased from 70 to 90 days after transplant-

ing and was lower than that of the second crop rice at comparable developmental stages (Fig. 1). Generally, leaf blades of rice plant possessed TNC concentrations fluctuated within a narrow range, i.e., 4 to 8% throughout the tested period of this experiment.

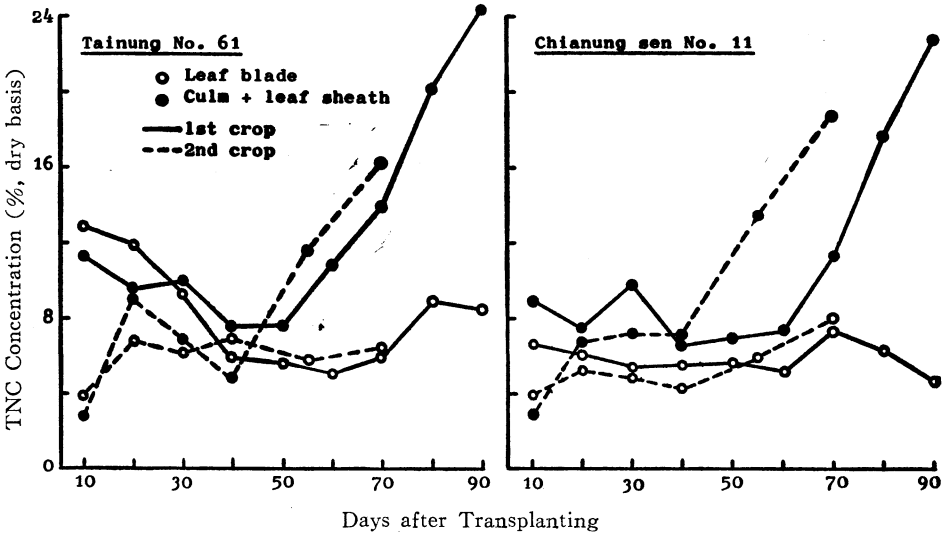

Fig. 1. TNC concentrations in plant fractions of developing rices grown in the first and second crop seasons in Taipei (1976-1977)

Fig. 1 also showed the carbohydrate status in rice culms from transplanting to heading in the two crop seasons of 1976-1977. For Tainung No. 61 variety grown in the first crop, TNC concentration decreased during the first 40 days and increased drastically starting from 50 days after transplanting (about 1 week before maximum tillering stage) to heading. It increased from 7.6 to 24.7% during this period. Accumulation of carbohydrates in culms of the second crop rice was also most evident in the 30 days prior to heading during which the panicles developed. However, the highest value (16.3 %) recorded at heading was 8.4% lower than that of the first crop rice. Developing Chianung sen No. 11 rice showed an almost identical pattern of changes in carbohydrate status (Fig. 1). TNC concentration peaked at heading stage in both crops. At this developmental stage, culms contained 22.6% of total dry weight as available carbohydrates in the first crop and the value was only 18.5% in the second crop.

Results of carbohydrate analysis of rices grown in 1978 at Taichung area were shown in Fig. 2. In the first rice crop, TNC concentrations in leaf blades were low at active tillering stage (about 35 days after transplanting) and reached the highest level (8 to 9 %) when the plants were gaining maximum number of tillers. It then declined steadily throughout the sampling period. In the second crop season, concentrations changed little until 51 days after transplanting. The decline thereafter was followed by an increase starting from booting toward heading stage. No significant difference in concentration or pattern of changes of leaf TNC was observed among the four varieties tested.

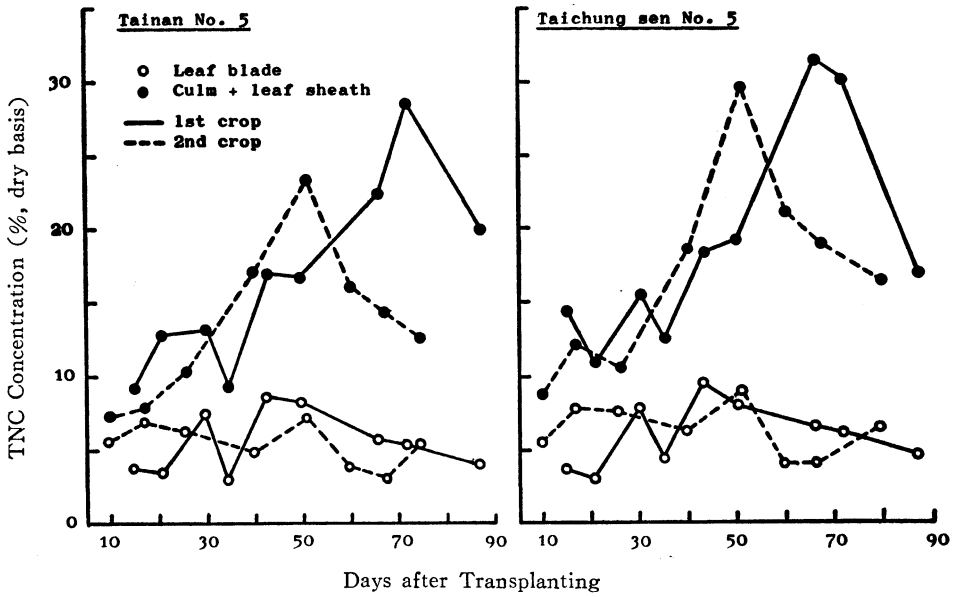

Fig. 2. TNC concentrations in plant fractions of developing rices grown in the first and second crop seasons in Taichung (1978)

Generally, total nonstructural carbohydrates accumulated continuously in the culms and leaf sheaths after transplanting and peaked around spikelet-formation stage in the 1978 experiments. Concentrations were then decreased with the advance of maturity (Fig. 2). A comparison between the two crop seasons in Taichung showed that culms of the second crop rice gained maximum level of TNC earlier than that of the first crop rice. Highest TNC concentrations were reached at 18 and 25 days before heading for the first and second crops, respectively, in this experiment. At comparable developmental stages , culms of rice plant had higher TNC percentages in the first than in the second crop season. This was especially true for the two japonica varieties at 18 days before heading where a difference up to 9% of total dry weight (29.4% vs. 20.2%) was observed in Tainung No. 67 rice. The difference in peak concentration between crops was less significant for indica varieties Taichung sen No. 5 and Taichung Native No. 1. With the only exception of Taichung sen No. 5, the other three varieties stored far more carbon energy in culms at heading in the first crop (averaged at 22.4%) than in the second crop season (11.9%).

Fig. 3 showed nitrogen concentrations in leaf and culm fractions of Tainan No. 5 and Taichung sen No. 5 rice varieties at various developmental stages. In contrast with total nonstructural carbohydrates, concentration of N was higher in leaves than in culms and a steady and marked decline was found in either fraction from initial tillering to panicle-formation stage (21 to 72 and 15 to 51 days after transplanting for the first and second crops, respectively). It increased slightly in both the leaves and culms during the last two to three weeks before heading. No varietal differences were observed

in terms of either N concentration or pattern of changes throughout the whole sampling period. However, N concentrations in tissues of rice plant grown in the first crop was higher during the first 50 to 60 days after transplanting and was lower thereafter until heading when compared with those at comparable stages in the second crop, indicating the existence of seasonal differences in the metabolism and accumulation of nitrogen in developing rice plant.

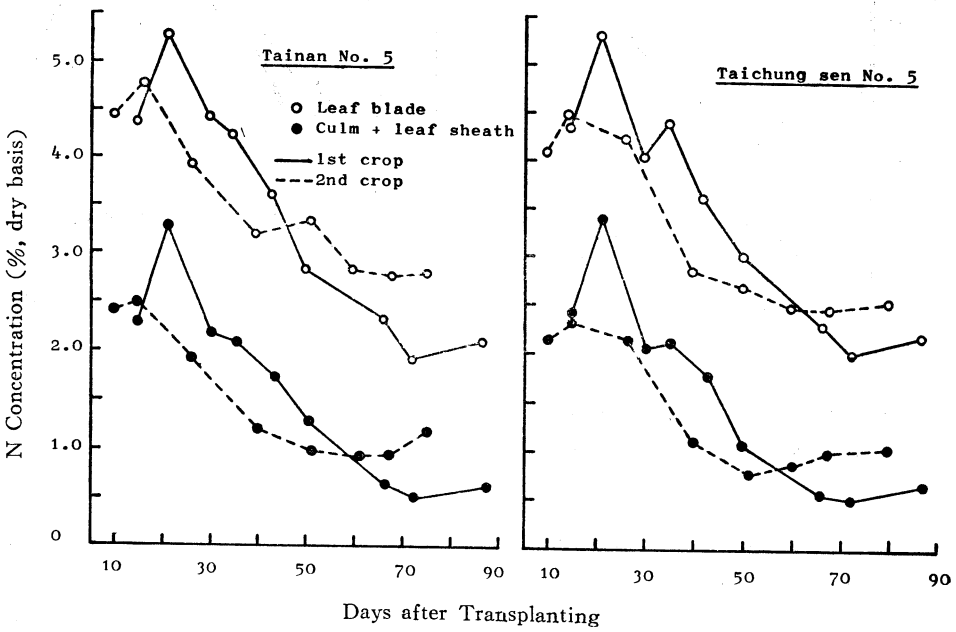

Fig. 3. Nitrogen concecntrations in plant fractions of developing rices grown in the first and second crop seasons in Taichung

Phosphorus concentrations of plant fractions compared between crops and among developmental stages were shown in Fig. 4. Phosphorus accumulation was more prominent in culms than in leaves for both rice crops. It is generally true that the first crop rice had higher P concentrations than the second crop rice except in early developmental period. Phosphorus concentrations of rice tissues also showed the tendency of declining with advancing maturity and reached minimum level around panicle formation stage. Sharp increase of P concentration in leaves and culms was a common characteristic in both the first and second rice crops. Comparison among varieties showed that indica rices had a higher P concentration at heading stage than japonica varieties.

Fig. 4 showed the status of potassium in plant fractions of developing rices. It was evident that K concentrations were higher in culms than in leaf blades during the whole period from transplanting to heading in either crop season. Declining K concentration in culms were found beyond 35 to 43 days after transplanting in the first crop rice. On the other hand, there was a gradual build-up of K concentration in leaf blades during the first 35 days of growth and the following decline was much slower than that in culms. Similar trends were also found when rice was grown in the second crop season.

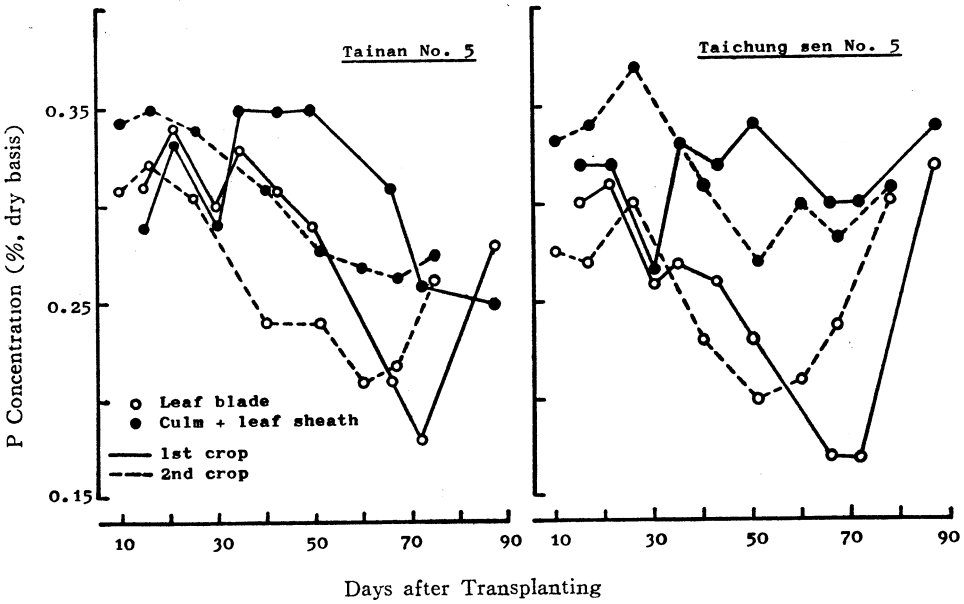

Fig. 4. Phosphorus concentrations in plant fsactions of developing rices grown in the first and second crop seasons in Taichung

Comparison between the two crops showed that in either the leaf blade or the culm, K concentrations were always higher in the first than in the second crop rice. When results were considered together with the changing pattern of dry weight with advancing maturity, it was probable that K was exported from leaf blades to panicles via culms in the later developmental period of rice plant.

Discussion

For 1978 experiments held in Taichung, the accumulation of dry matter at heading stage was similar between the two crops. However, rices grown in the second crop had a heavier leaf dry weight and a lighter culm dry weight than those grown in the first crop season, indicating less pre-stored energy source in stems and leaf sheaths at this stage. High temperature during the early growth phase of the second crop rice tended to cause vigorous vegetative growth. Lian *et al.* [8] reported that dry weight of total plant at flowering was slightly higher for the second crop rice but showed no difference at harvest. In most cases, excessive early vegetative growth is not desirable since it tends to depress grain yield of rice [4].

In Taipei area, culms of the first crop rice had higher TNC concentrations than those of the second crop rice and maximum levels of TNC were obtained just before heading in both crop seasons (Fig. 1). Similar results were also found in Taichung experiments but the highest concentrations were recorded much earlier, i. e., 18 days before heading for the first crop rice and 25 days before heading for the second (Fig. 2). In the southern part of Taiwan (Pingtung), Lian and Chen [9] found that total

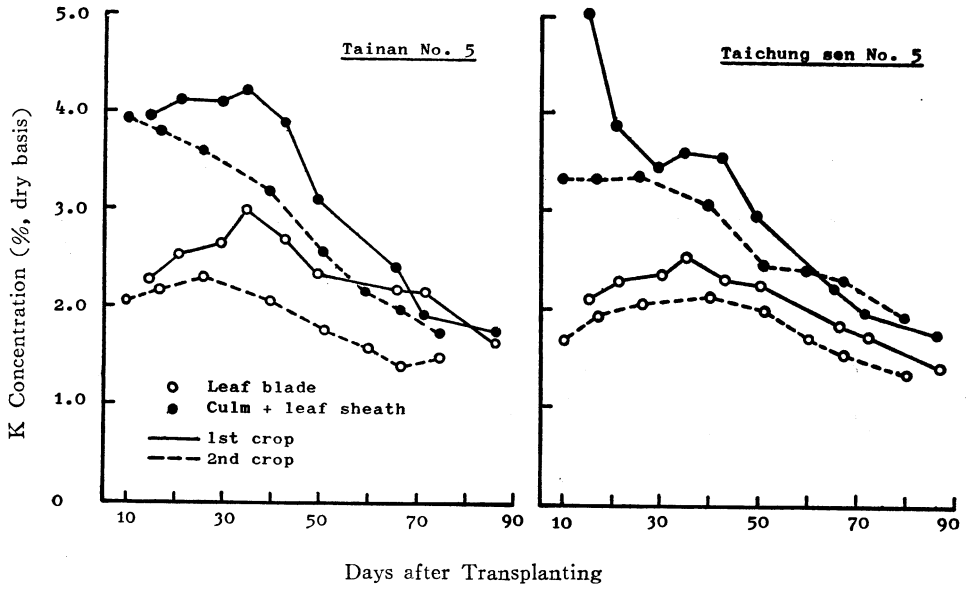

Fig. 5. Potassium concentrations in plant fractions of developing rices grown in the first and second crop seasons in Taichung

carbohydrates in straws peaked at heading stage for IR-8 and Chianan No. 8 rices. Tai [22] and Lin and Tai [12] also pointed out the stages between booting and heading as the occurrence of maximum total carbohydrate concentrations in four rice varieties. The fact that indica rices had more TNC accumulated in culms than japonica varieties in the second crop (Figs . 1 and 2) might indicate varietal difference in adaptation to specific environmental conditions.

Leaf blades contained little starch and their carbohydrate storage was minor as compared with that in culms and sheaths [17]. As shown in Fig. 2, TNC concentrations of leaf blades kept decreasing from 43 days after transplanting in the first crop. However, there was an increase starting from 60 days after transplanting in the second crop season. This, together with the decreasing TNC levels in culms, might suggest an accumulation of carbohydrates in leaf blades and a subsequent retardation of leaf photosynthetic activity. Lin and Su [11] found that both activity and efficiency of photosynthesis were lower in the second crop. The relationship between photosynthesis and carbon deposition into culms and panicles in the two crops should be further studied when low yield of the second crop rice is concerned.

Carbohydrates stored in culms before heading could be translocated to grains and thus contribute to grain yield [25]. Results of this experiment showed that TNC concentration at heading was much higher in the first than in the second rice crop. Liu [13] also stated that TNC concentrations were low in culms when rices were grown under high or high-to-low temperature regimes. Yoshida [25] pointed out the possible contribution of stored carbohydrates to rice yield was large at low nitrogen levels or when light intensity after heading was low. As the second crop rice in Taiwan receives less N fertiliza-

tion and is under low solar radiation at the grain-filling period, it is meaningful to attempt increasing TNC in plant tissues by improving cultural practices or by variety selection in order to enhance rice yield in the second crop season.

It is widely recognized that N is essential in promoting tillering of rice plant. Fig. 3 showed that rices grown in the first crop season had higher N concentration in either leaves or culms at tillering stage than those grown in the second crop season. Such difference may be one of the factors in restricting the tillering capacity of the second crop rice. Thenabadu (cf. 23) suggested a critical N value of 2.4% in the most recently matured leaf when rice plant was at the stage of growth between maximum tillering and panicle emergence. Results of this report showed that the average N concentrations of all leaves of the second crop rice were well beyond the critical level, indicating the presence of sufficient nitrogen at this stage. Furthermore, N concentrations in leaf blades of the second crop rice were comparable or even higher than those of the first crop rice at stages close to heading. However, Lin [10] and Lin and Su [11] found that physiological characters related closely to N nutrition, such as chlorophyll concentration and photosynthetic activity, for rices in the second crop were inferior to those in the first crop. It is probable that composition of N compounds was different between the two crop rices. In other words, whether a proper proportion of N-containing compounds is in functional or active form might be important in dealing with the poor growth of the second crop rice.

Murata [14] reported that N applied at earlier stage of growth was effective in increasing the carbohydrate accumulation at maturity, but N applied at later stage of growth was effective only when the level of N at earlier stage was not too high. He also concluded that low N-response rice varieties tended to be superior in N accumulation but inferior in their ability of carbon assimilation. These assumptions were in accordance with the results of this experiment as the first crop rice had higher N concentrations at the vegetative phase and accumulated more TNC in culms during the reproductive growth stage. More information is still needed in interpreting N-C interaction because the effect of N levels on TNC metabolism had not been tested in this experiment.

Phosphorus was also necessary to promote tillering of rice (Dr. T. F. Chiu, TARI, personal communication) and was essential in carbohydrate metabolism [3]. Results on P of this study was erratic, however, the first crop rice tended to have higher concentrations except in the early developmental period. Deposition of P into culms and the sharp increase in leaves before heading suggested active carbohydrate interconversions and accumulation in plant tissues.

Lian [6] reported the retardation of K uptake of the second crop rice, resulting in lower K concentrations in plant. Similar results were found in this experiment. As the major element required for growth, K is accumulated at high concentrations by plants. It is also essential for the breakdown and formation of starch and the translocation of chemical constituents among organs. The high K concentrations in the first crop rice (Fig. 5) might indicate active carbohydrate metabolism and redistribution which were

possibly beneficial to the development of panicles before and after heading. Greater response to K fertilization of the second crop rice was demonstrated by Lian[6], indicating insufficient supply of this element for normal functioning. Further studies will be made in this laboratory to explore connections between K requirement and the biochemical processes of protein and carbohydrate metabolism grown in the second crop season.

In conclusion, we suggest that less amount of total nonstructural carbohydrates stored in culms and leaf sheaths before the onset of panicle emergence, lower concentrations of potassium in vegetative organs, and the composition, rather than concentration, of nitrogen present in plant fractions, especially leaf blades, are some of the physiological problems must be solved in order to obtain a higher yield of the second crop rice in Taiwan.

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Literature Cited

1. Association of Official Agricultural Chemists. 1970. Official methods of analysis (11th ed.). Method 3.060. The Association : Washington, D. C.
2. Cock, J. H. and S. Yoshida. 1972. Accumulation of ^{14}C-labelled carbohydrate before flowering and its subsequent redistribution and respiration in the rice plant. Proc. Crop Sci. Soc. Japan 41 : 226-234.
3. Epstein, E. 1972. Mineral nutrition of plants : principles and perspectives. John Wiley& Sons, Inc., New York.
4. International Rice Research Institute. 1972. Annual report. Los Banos, Phillipines.
5. Issac, R. A. and J. B. Jones, Jr. 1972. Effects of various dry ashing temperatures on the determination of 13 nutrient elements in five plant tissues. Comm. Soil Sci. Plant Anal. 3 : 261-269.
6. Lian, S. 1978. An investigation on yield decline in the second rice crop as affected by soil and relating factors. J. Agri. Assoc. China NS 101 : 35-55. (in Chinese with English summary)
7. Lian, S. and A. Tanaka. 1967. Behaviour of photosynthetic products associated with growth and grain production in the rice plant . Plant Soil 26 : 333-347.
8. Lian, S., Y. L. Wu and H. T. Chen. 1969. Growth performance and yield of the rice plants in the first and second crop seasons in Pingtung area. J. Taiwan Agri. Res. 18 : 1-16. (in Chinese with English summary)
9. Lian, S. and H. T. Chen. 1970. Comparison on growth performance and yield of Chianan 8 and IR 8 in Pingtung area. J. Taiwan Agri. Res. 19 : 51-61. (in Chinese with English summary)
10. Lin, A. C. 1979. Comparison on the photosynthesis under community conditions between the first and second crops of rice. *In* The causes of low yield of the second crop rice in Taiwan and the measures for improvement (S. C. Hsieh and D. J. Liu ed.). Natl. Science Council, R. O. C. (in Chinese with English summary)
11. Lin, A. C. and H. Su. 1976. Studies on the causes of low yielding in the second crop of rice in Taiwan. I. Comparison of the photosynthesis under community conditions between first and second crop of rice. Natl. Science Council Monthly 4 (11) : 5-21. (in Chinese with

English summary)

12. Lin, M. L. and K. S. Tai. 1979. Comparative studies on the accumulation of photosynthetic products and panicle growth process of the first and second rice crops in Pingtung area. Natl. Sci. Council Month'y 7 (4) : 394-400. (in Chinese with English summary)
13. Liu, D. J. 1979. Influence of temperature at various growth stages on the accumulation and translocation of carbohydrates in rice plant. *In* The causes of low yield of the second crop rice in Taiwan and the measures for improvement (S. C. Hsieh and D. J. Liu ed.). Natl. Sci. Council, R. O. C. (in Chinese with English summary)
14. Murata, Y. 1968. Physiological responses to nitrogen in plants. *In* Physiological aspects of crop yield (J. D. Estin *et al.* ed.). Amer. Soc. Agron., Madison, Wisc.
15. Murayama, N., M. Oshima and S. Tsukahara. 1961. Studies on the metabolism of rice plant during the ripening period. VI. Marking of accumulated carbohydrates in the stem and research on their translocation by use of 14-C. J. Sci. Soil Manure Japan 32 : 261-265.
16. Oshima, M. 1966. Translocation and redistribution of the assimilated 14-C in rice plant. J. Sci. Soil Manure Japan 37 : 589-593.
17. Perez, C. M., E. P. Palmiano, L. C. Baun and B. O. Juliano. 1971. Starch metabolism in the leaf sheaths and culm of rice. Plant Physiol. 47 : 404-408.
18. Raguse, C. A. and D. Smith. 1965. Carbohydrate content in alfalfa herbage as influenced by methods of drying. J. Agri. Food Chem. 13 : 306-309.
19. Smith, D. 1969. Removing and analyzing total nonstructural carbohydrates from plant tissue. Wis. Agri. Exp. Sta. Res. Rep. 41, 11pp.
20. Stoy, V. 1963. The translocation of 14-C labelled photosynthetic products from the leaf to the ear in wheat. Physiol. Plant. 16 : 851-866.
21. Stoy, V. 1965. Photosynthesis, respiration and carbohydrate accumulation in spring wheat in relation to yield. Pihysol. Plant. Supplementum IV.
22. Tai, K. S. 1978. Improvement of the low yielding of second rice crop in Kaohsiung and Pingtung area. 2. Physiological behaviour of delaying sowing date of second rice crop. J. Agri. Assoc. China NS 102 : 24-42. (in Chinese with English summary)
23. Westfall, D. G., W. T. Flinchum and J. W. Stansel. 1973. Distribution of nutrients in the rice plant and effect of two nitrogen levels. Agron. J. 65 : 236-238.
24. Wu, H. P., I. Y. Liao, M. H. Chien, T. L. Lin, Y. S. Chen, Y. P. Wang, K. H. Tsai, L. K. Wu, W. L. Chang, F. H. Lin and Y. L. Wu. 1975. The investigation on the causes of low yielding in the second crop of rice. Natl. Sci. Council Monthly 3 (10) : 5-39.
25. Yoshida, S. 1972. Physiological aspects of grain yield. Ann. Rev. Plant Physiol. 23 : 437-464.
26. Yoshida, S. and S. B. Ahn. 1968. The accumulation process of carbohydrate in rice varieties in relation to their response to nitrogen in the tropics. Soil Sci. Plant Nutri. 14 : 153-162.

期作間水稻不同器官內碳水化合物與氮磷鉀濃度變化比較[1]

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摘 要

本試驗在臺北與臺中二地區進行，於水稻生育各重要階段測定不同器官內之非構造性碳水化合物、氮、磷與鉀濃度，並比較期作間之差異，以明瞭臺灣地區二期作水稻低產的生理原因。

水稻之稈與葉鞘，在幼穗分化與發育期間，明顯的累積非構造性碳水化合物（TNC），1978年臺中地區試驗發現，一期作水稻於抽穗前 15 天之 TNC 濃度最高，二期作則於抽穗前28天最高；1976—1977年臺北地區兩期作均於抽穗時達到最高濃度。期作間之比較顯示，一期作水稻抽穗期稈部貯存之碳水化合物總量遠超過二期作。

水稻葉片部位之氮素濃度較高，但稈與葉鞘之磷、鉀濃度超過葉片。一期作生育初期葉片之氮濃度高於二期作，但至幼穗發育階段，差異已不明顯，二期作甚至有偏高的趨勢。葉片與稈部之鉀濃度方面，則任何生育階段均以一期作爲高。水稻於抽穗前貯存之碳水化合物不足，葉片內較低的鉀濃度，以及植株內氮素的組成而非濃度，可能爲二期作水稻低產的重要生理原因。

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